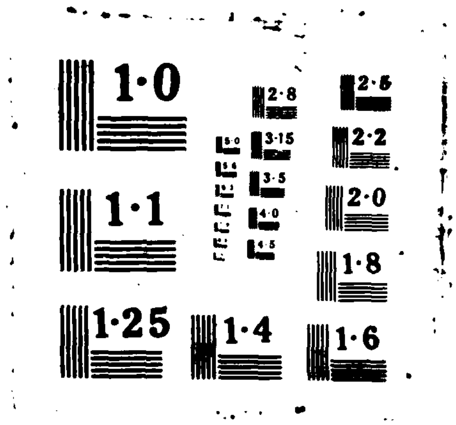
AD-A170 274 GEOMAGNETIC ACTIVITY AND NORTH-SOUTH ASYMMETRY OF COSMIC RAYS CIRCA 1 GV(U) WASHINGTON UNIV SEATTLE SPACE SCIENCES DIV J T ELY ET AL. 26 SEP 86 N00014-77-C-0392

1/1

UNCLASSIFIED F/G 4/1 NL

END
4-87
DTIC


1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
4·5
1·8
1·25
1·4
1·6

SECURIT

AD-A178 274

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT unlimited distribution
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION University of Washington	6b. OFFICE SYMBOL (If applicable)
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) Seattle, Washington 98195	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Office of Naval Research	8b. OFFICE SYMBOL (If applicable)
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-77-C-0392	
8c. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, Virginia 22217-5000	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
662300			

DTIC ELECTE MAR 24 1987 S A

11. TITLE (Include Security Classification)
Space Weather Coupling

12. PERSONAL AUTHOR(S)
Ely, John T. A. and Huang, Tsai Chi

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 3/1/77 TO 9/30/84	86Sept26	9

16. SUPPLEMENTARY NOTATION
(61-5683)

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Solar activity; sun-weather problem; geomagnetic activity, cosmic ray modulations; upper tropospheric ionization; cyclonic vorticity; lightning frequency, cirrus

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Various features of solar-sector synchronous modulations of the particulate cosmic radiation reaching the earth's atmosphere have been studied using satellite and surface data. The flux in the broad maximum of the galactic cosmic ray differential spectrum (near 1 Gv rigidity) exhibits an intermittent north-south asymmetry in mid and high geomagnetic latitudes. This modulation exhibited a strong association with geomagnetic disturbance index and interplanetary magnetic field direction during the 1964 and 1965 years of sunspot minimum. Such correlations are consistent with the predictions of a theory that attributes the north-south asymmetry to reconnection of the interplanetary and geomagnetic fields. This finding is also consistent with suggestions that solar activity influence on atmospheric processes may be mediated by the resulting modulations of upper tropospheric ionization.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL R. Gracen Joiner	22b. TELEPHONE (Include Area Code) (202)696-4216
22c. OFFICE SYMBOL	

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Final Report under Office of Naval Research
Contract N00014-77-C-0392
Space Weather Coupling

9-26-86

GEOMAGNETIC ACTIVITY AND NORTH-SOUTH ASYMMETRY OF COSMIC RAYS CIRCA 1 GV

J. T. A. Ely and T. C. Huang

Space Sciences Division
Geophysics Program
University of Washington, Seattle

Dist

A-1

(unlimited distribution)

Abstract. Various features of solar-sector synchronous modulations of the particulate cosmic radiation reaching the earth's atmosphere have been studied using satellite and surface data. The flux in the broad maximum of the galactic cosmic ray differential spectrum (near 1 Gv rigidity) exhibits an intermittent north-south asymmetry in mid and high geomagnetic latitudes. This modulation exhibited a strong association with geomagnetic disturbance index and interplanetary magnetic field direction during the 1964 and 1965 years of sunspot minimum. Such correlations are consistent with the predictions of a theory that attributes the north-south asymmetry to reconnection of the interplanetary and geomagnetic fields. This finding is also consistent with suggestions that solar activity influence on atmospheric processes may be mediated by the resulting modulations of upper tropospheric ionization.

Introduction

Two modulations of galactic cosmic rays at earth, discovered in 1967 satellite data, have been previously described according to a magnetic coupling model. That model explained the modulations as due to combined effects of the interplanetary and geomagnetic fields (IMF and GMF) (Ely, 1977). One of the modulations was a north-south asymmetry (NSA) in which the flux from 400 Mev (rigidity ca. 1 Gv) to over 1 Gev/nucleon was observed to decrease approximately 30% in mid to high northern geomagnetic latitudes during positive sectors of the interplanetary magnetic field (IMF away from the sun), and in southern latitudes during negative sectors (IMF towards the sun). The NSA was ascribed to reconnection between the GMF and the IMF, in that the galactic cosmic ray flux is expected to decrease rapidly in the flux tube between the connected pole and the sun (since the sun is not a significant source at these energies).

In the other modulation, the equatorial flux also exhibited an IMF sector polarity dependent variation of similar amplitude, but showed a seasonal character with opposite phases in summer and winter. That modulation was explained to result from parallel and antiparallel configurations of the IMF and GMF affecting cutoff rigidities. Both modulations exhibited similar rigidity dependence and were found at about 1% amplitude ca. 10 Gv in cosmic ray neutron monitor (NM) data. The smaller amplitudes seen in the NM records are consistent with the higher mean rigidity of primaries contributing to those data. Both modulations appeared to exhibit complex behavior, the NSA amplitude becoming maximum and the equatorial modulation disappearing completely near the 1964-1965 sunspot minimum. The NSA appeared to be associated with increases in the geomagnetic disturbance index, ap, consistent with the GMF-IMF reconnection etiology proposed by the magnetic coupling model. To more precisely define the association of NSA with ap elevation is the principal purpose of the work reported here. In essence, the magnetic coupling model suggests: (1) the cosmic ray flux from mid to high latitudes (in regions including the GMF cusps) should be maximum when GMF-IMF reconnection is not taking place and the GMF is undisturbed (i.e. ap near 0); and (2) over some range of ap, the cosmic ray flux will decrease near latitudes connected to the sun (northern in positive and southern in negative IMF sectors) when reconnection is occurring. Testing of this two part hypothesis is the major

formal goal of the work reported here. The magnetic coupling model does not predict the more complex rigidity dependent effects at the unconnected poles. The small amount of satellite data evaluated near 1 Gv did not show significant change in cosmic ray counting rate in the unconnected region. The somewhat higher rigidity neutron monitor data examined here are seen to exhibit a distinct but significantly smaller decrement at the unconnected pole. Analysis of this complex issue is not the goal of the present paper, and comment is merely incidental.

Interest in these modulations and in the resulting changes in upper troposphere ionization is largely motivated by their possible effects on atmospheric processes. The existence of such changes over the eleven-year solar cycle and their possible importance to the sun-weather problem were pointed out by Ney (1959). The existence also of short term changes (on a scale of days) as well as mechanisms to explain the influence of all such ionization changes on climate, weather, high cirrus cloud formation, droughts, cyclonic vorticity and lightning frequency have also been described (Ely, 1977, 1979, 1984).

Correlations have been reported between most of these and solar activity with high (>3 sigma) statistical significance (Eddy, 1976, 1979; Stuiver, 1961; Mitchell et al, 1977; Roberts and Olson, 1973; Wilcox et al, 1974; Hines and Halevy, 1977; Lethbridge, 1981; Scherrer, 1979; Herman and Goldberg, 1978). Because of interest in the possible role of the modulations studied here as mediators of the solar activity influence on atmospheric processes, several analyses are in progress utilizing more data than were available for the earlier study. The importance of tropospheric ionization by cosmic rays as a possible mediator of the sun-weather correlations is amplified by the paucity of possible candidates to perform the coupling (Dessler, 1975).

This paper presents an analysis of the north-south asymmetry modulation during the 1964-1965 two year period including sunspot minimum. For this interval, we show below that the NSA exists and exhibits a highly significant association ($p<<.001$) with the magnetic disturbance, index, ap, as the reconnection hypothesis suggests.

Data Selection and Analysis

The NSA modulation was first observed in 1967 satellite data and then confirmed in NM data recorded from 1964 through 1968. The NSA was found to have a large amplitude in the sunspot minimum years 1964 and 1965. The satellite (OV1-86) measured cosmic rays above 400 Mev/nucleon, and provided information on the radiation producing most of the ionization in the upper troposphere. Although a great deal of data exists for lower energy proton and alpha fluxes (up to a few Mev), very little have been recorded at the energies above 400 Mev/nucleon (with ranges above 200 grams/cm^2 necessary to reach the upper troposphere) on low altitude polar orbits (necessary to cover the earth and define the atmospheric region "illuminated" through the instrument aperture). Surface neutron monitors (NM) provide continuous records of cosmic ray fluxes in the geomagnetic latitude regions of maximum NSA indicated by the satellite data. Because high energy primaries dominate the NM records (via atmospheric shielding and collision multiplicity effects), approximately half the counts

are due to energies above 10 Gev, and the NSA amplitude is usually less than 1% in these data. Nevertheless, the large quantity of continuous NM records provide a means of readily examining the ap association of NSA near the 1964-1965 sunspot minimum, a time when the other cited evidence suggests the NSA was present. The additional studies in progress are designed to define the NSA behavior up to the present time.

For these reasons, northern (Deep River) and southern (Mt. Wellington) NM records for the 2 year period from January 1, 1964 through December 31, 1965 as well as ap data were obtained on magnetic tape from the NOAA World Data Center-A at Boulder. The IMF sector polarities for the same years were obtained from the Stanford University Center for Space Science and Astrophysics. Data processing was accomplished on a VAX 11-780. The input data were read from tape to disc where NM records for both stations were binned as normalized hourly count rates according to IMF sector polarity (positive or negative) and according to ap amplitude. Normalization was accomplished for each hour of NM data through division by the most recent hourly count rate at which ap was near zero (to remove secular trends such as sunspot cycle changes). Of the 17,161 hours of data processed for each NM, 86% occurred at values of ap < 15 and are included in the figures. For ap < 2 no significant NSA was detected. From ap=2 to 15, the NM decrement (modulation) increased approximately linearly and exhibited the NSA. For the remaining 14% of the data, ap ranged from 15 to 179. These highly disturbed data have not been included here because of very poor statistics and the probable dominance of other effects than "quasi-linear" reconnection. The resulting representations of the raw data are displayed as Figures 1 and 2. To produce Figures 3 and 4, the ordinates of Figures 1 and 2 were filtered by calculating weighted moving averages of order 3 (Spiegel, 1961) as follows: one half the NM rate (ordinate) at each value of ap was added to one fourth the NM rates for both the previous and following values of ap.

Results and Discussion

The magnetic coupling model predicts that the galactic cosmic ray counting rate will decrease (and, conversely, that solar cosmic rays will increase) at the top of the atmosphere in regions connected to the sun by IMF-GMF merging. In this and related papers, we define the amplitude of the resulting NSA for a given NM station (at each ap value) as the difference between the counting rates in positive and negative IMF sectors (NM(+)-NM(-)). Each of the four figures represents over 17,000 hours (2 years) of data recorded at one of two NM stations. The stations differ in two important respects. At Mt. Wellington, the count rate is 30 times lower (6×10^4 per hour vs. 1.8×10^6 at Deep River), and the cut-off rigidity is nearly 2 times higher (1.89 Gv vs. 1.02). Both of these differences reduce the NSA amplitude at Mt. Wellington. The maximum standard deviation (sigma) for counting statistics in the ap range of interest (3 to 15) at Deep River is .00004, five times smaller than the corresponding .0002 value at Mt. Wellington. As a result, the separation between the positive and negative IMF sector data is over 25 sigma for the former station but ranges from only 2 to 8 sigma for the same 8 ap values at the latter. Nevertheless, even at Mt. Wellington the separation (i.e. the NSA) is highly significant ($p \ll .001$) from ap = 3 to 15 inclusive, as can be seen by forming the product of 8 probabilities, the smallest of which is $p < .05$. We have not yet determined the cause of the anomalous transient in the negative IMF sector data at Deep River for ap = 6 and 7. However, its existence does not affect our conclusions.

In addition to the statistical noise due to low counting rate, the NSA was also reduced by another effect at Mt. Wellington, as can be seen in the filtered data of Figure 4. We suggest this is due to the higher cut-off rigidity because the separation (NSA) must approach zero as rigidity increases without limit. The rigidity dependence of the NSA amplitude has been summarized elsewhere (Ely, 1977); its steeply falling character is seen from the 30% value at 1 Gv (satellite) and the 0.1% seen in the 2 to 10 Gv range (Mt. Wellington NM).

In the satellite data, there was no significant decrease observed in the count rate for the unconnected regions (north in IMF negative, and south in IMF positive sectors). This "complete" asymmetry at 1 Gv facilitates the magnetic coupling model explanations of several atmospheric processes including the correlations of lightning incidence and of cyclonic vorticity with respect to IMF sector boundary passage. In the NM records, however, a decrease in count rate is seen in both the connected and unconnected data (differing in amplitude, of course, by the NSA). As mentioned earlier, discussion of the decreased asymmetry in the higher rigidity NM data (due to effects at the unconnected pole) is beyond the scope of this paper but has no bearing on the conclusions presented here.

Conclusions

In the data sets analyzed here, the NSA: (1) is not significant in raw data during quiet times (ap < 2; 17% of the data); and (2) is present for ap values from 3 to 15, inclusive, as a highly significant difference in the IMF positive and IMF negative count rates ($p \ll .001$). This work constitutes a

positive test of the magnetic coupling model predictions and hence is supportive of a theory which offers explanations for coupling between solar activity and atmospheric processes.

Acknowledgements. We thank Drs. J. J. Lord, G. K. Parks, and R. J. Wilkes for helpful comments. The generous sharing of data and opinions by Drs. J. M. Wilcox (prior to 1983), P. H. Scherrer, and J. T. Hoeksema of the Stanford University Center for Space Science and Astrophysics are appreciated. The skilled assistance of Vi Miller of NOAA's World Data Center-A (Boulder) has long been of great value. The work was supported by USRA Contract NAS8-35530, and ONR Contract N00014-77-C-0392.

References

Dessler, A. J., Some problems in coupling solar activity to meteorological phenomena, NASA Special Pub. 366, 187-197, 1975.

Eddy, J. A., The Maunder minimum, Science, 192, 1189-1202, 1976.

Eddy, J. A., Climate and the changing sun, Climate Change, 1, 173-190, 1977.

Ely, J. T. A., Equatorial modulation and north-south asymmetry of galactic cosmic rays due to the interplanetary magnetic field, J. Geophys. Res., 82, 3643-3648, 1977.

Ely, J. T. A., Solar activity and terrestrial weather: the magnetic coupling model, NASA Conference Pub. 2098, A 25-26, 1979.

Ely, J. T. A., Cosmic rays, solar activity, magnetic coupling, and lightning incidence, NASA Contractor Report 3812, 1-14, 1984.

Herman, J. R., and R. A. Goldberg, Sun, Weather, and Climate, NASA SP-426, 1978.

Hines, C. O., and I. Halevy, On the reality and nature of a certain sun-weather correlation, J. Atmos. Sci., 34, 382-404, 1977.

Lethbridge, M. D., Cosmic rays and thunderstorm frequency, Geophys. Res. Lett., 8, 521-522, 1981.

Mitchell, J. M., C. W. Stockton, and D. M. Meko, Drought cycles in the United States and their relation to sunspot cycle since 1700 A.D., EOS, 58, 694, 1977.

Ney, E. P., Cosmic radiation and the weather, Nature, 183, 451-452, 1959.

Roberts, W. O., and R. H. Olson, Geomagnetic storms and winter-time 300-mb trough development in the North Pacific-North America area, J. Atmos. Sci., 30, 135-140, 1973.

Scherrer, P. H., Solar variability and terrestrial weather, Rev. Geophys. Space Phys., 17, 724-731, 1979.

Spiegel, M. R., Theory and Problems of Statistics (Schaum's Outline Series), 359 pp., McGraw-Hill, New York, 1961.

Stuiver, M., Variations in radiocarbon concentration and sunspot activity, J. Geophys. Res., 66, 273-276, 1961.

Wilcox, J. M., P. H. Scherrer, L. Svalgaard, W. O. Roberts, R. H. Olson, and R. L. Jenne, Influence of solar magnetic sector structure on terrestrial atmospheric vorticity, J. Atmos. Sci., 31, 581-588, 1974.

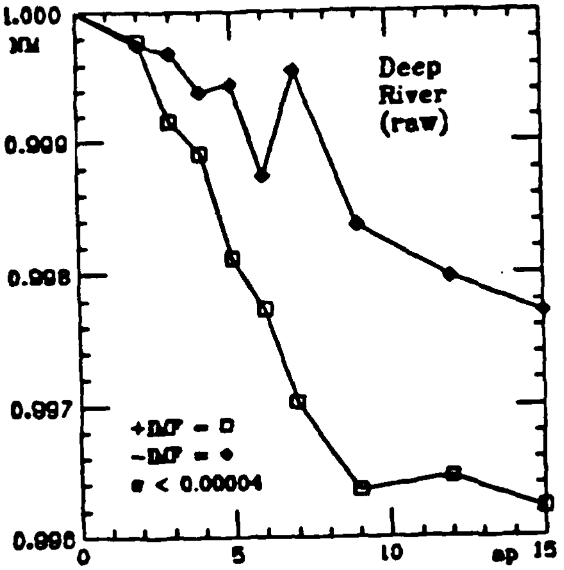


Figure 1. Deep River neutron monitor (NM) count rates (raw) in IMF positive and negative sectors as a function of geomagnetic disturbance (ap) for the years 1964 and 1965 of sunspot minimum.

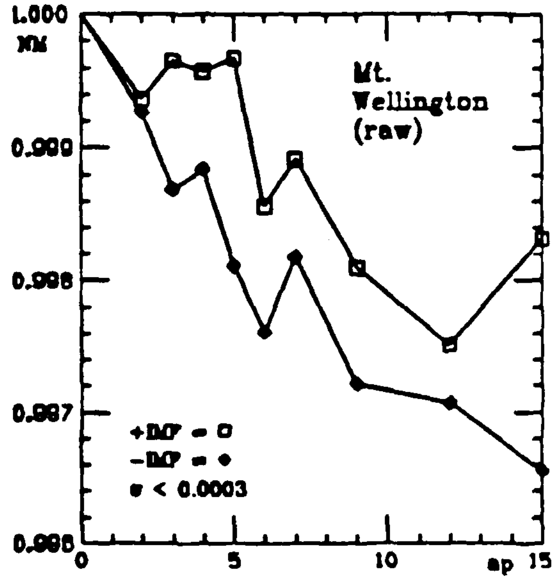


Figure 2. Mt. Wellington NM data (raw); the same conditions described in Figure 1 apply to all 4 figures. The high noise content results primarily from the low count rate of this NM.

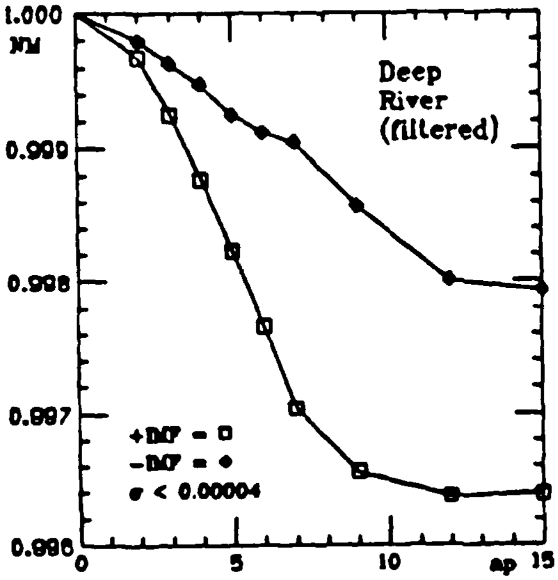


Figure 3. Deep River NM (filtered to attenuate the statistical noise). Notice the value of sigma given is determined by counting statistics only.

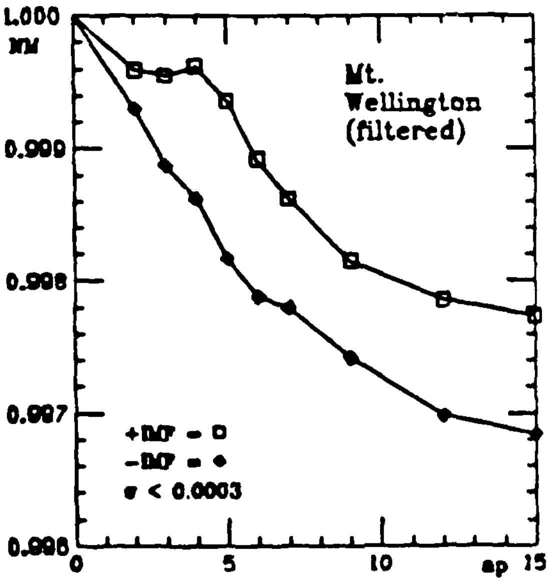


Figure 4. Mt. Wellington NM (filtered). In comparison with the Deep River plots, the smaller separation of the two curves and the smaller value of maximum slope are both ascribed to the higher cutoff rigidity at Mt. Wellington (see text).

Figure Captions

Figure 1. Deep River neutron monitor (NM) count rates (raw) in IMF positive and negative sectors as a function of geomagnetic disturbance (ap) for the years 1964 and 1965 of sunspot minimum.

Figure 2. Mt. Wellington NM data (raw); the same conditions described in Figure 1 apply to all 4 figures. The high noise content results primarily from the low count rate of this NM.

Figure 3. Deep River NM (filtered to attenuate the statistical noise). Notice the value of sigma given is determined by counting statistics only.

Figure 4. Mt. Wellington NM (filtered). In comparison with the Deep River plots, the smaller separation of the two curves and the smaller value of maximum slope are both ascribed to the higher cutoff rigidity at Mt. Wellington (see text).

END
4-87
DTIC